Advanced Composite Coatings
June 2006

Corrosion is a challenge that crosscuts all industries and is estimated to cost U.S. industry $300 billion per year. Although corrosion-resistant coatings are currently in use, enhanced performance requires improved coating materials and coating methods. Cost-effective coatings save money by increasing the lifetime of industrial components and by allowing less expensive substrate and coating combinations to substitute for expensive base materials. Pacific Northwest National Laboratory (PNNL) partnered with University of Washington; University of Central Florida; Air Products and Chemicals, Inc.; Solar Turbines; SRI, Inc.; and Starfire Systems to develop a new ceramic-based coating for steel and superalloys.

The goal of the project was to develop low-cost ceramic coating for prevention of high-temperature (700-1000^{o}C) corrosion of metals in industries such as chemical processing and industrial power generation. This coating protects the base metal from oxidation, metal dusting, carburization, and sulfidation. The coating is fabricated at significantly lower temperature than typically required for conventional ceramic coatings; therefore the new process saves energy and reduces harmful emissions. It is estimated that energy savings of over 14 trillion Btu per year could be obtained through enhanced corrosion resistance and productivity resulting from use of these coatings.

This project focused on a two-step approach to synthesis and fabrication of ceramic-composite coatings suitable for large-scale field application: pyrolysis of preceramic precursors and in-situ displacement reaction synthesis. Non-oxide ceramic materials derived from inorganic preceramic polymers were selected because they have been found to possess exceptional high-temperature stability and oxidation resistance. Low-temperature processing and the ability to create customized microstructures make this an attractive coating process.

The coating is created by mixing a liquid preceramic polymer with aluminum metal-flake powders to form a slurry, which can be applied to a metal object. The coating application is done by painting, which can be dipping, brushing, or spraying (see Figure 1). This is followed by a low-temperature curing process using a commercial ruthenium-based catalyst, which enables polymer cross-linking and dries the slurry to a green state.

Figure 1: Polymer/filler slurry can be applied like paint in air at ambient conditions: dipping, spraying, painting.

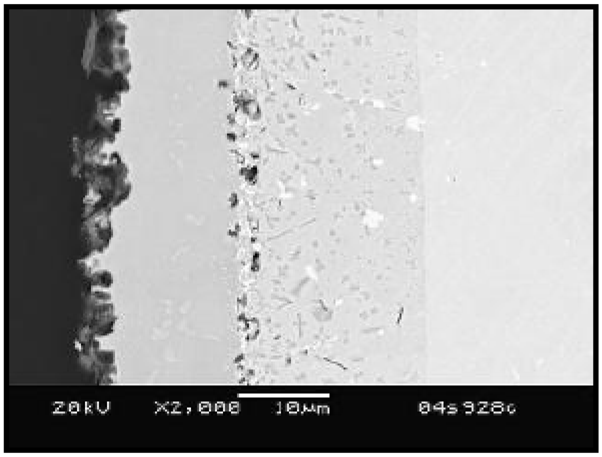

Figure 2: An electron micrograph of a coated 316-stainless steel (SS) coupon in cross-section shows the diffusion-reaction layers. Starting from the left hand side of the photo, which is the surface of the coupon, the following layers are formed: 1) Aluminum oxide outer layer (not visible at lower magnifications), 2) FeAl layer, 3) Fe_3Al inner layer, and 4) 316SS as graded underlayer.

The coated steel then undergoes a simple pyrolysis cycle at 800°C to 1000°C in air, nitrogen, or argon. The heat converts the green state layer into an aluminum diffusion/reaction layer that permeates the surface of the steel and provides an aluminide surface coating on the steel. Coatings produced by these methods are tough and corrosion resistant, with superior mechanical properties (wear, spallation resistance, etc.) compared to conventional coatings. Multiple and graded coatings are also feasible (see Figure 2).

Advanced composite coating technology may be applied for hydrogen production, petrochemical industry, coal- and gas-based electrical power generation, and other high-temperature corrosion resistance applications such as heat exchanges, engines, pipes, and construction materials.

For more information about advanced composite coatings, contact Charles Henager, Jr. at PNNL at (509) 376-1442 or chuck.henager@pnl.gov. Additional information about this project is available at
http://www.eere.doe.gov/industry/imf/pdfs/1791_advanced_compositecoatings.pdf